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Ecosystem Services and Financial Benefits from Urban Green Spaces using The i-Tree Eco Model: A Case Study of *Anandabana*, Bhubaneswar

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***Abstract*:** This study evaluated ecosystem services offered by *Anandabana* (Urban green space), a curated urban forest in Bhubaneswar, Odisha, using the i-Tree Eco model developed by the U.S. Forest Service. The study aimed to quantify carbon storage and sequestration provided by prominent tree species within the park and to assess the applicability of the i-Tree Eco model in an Indian urban context. Field data were collected from 484 individual trees of *Acacia auriculiformis, Adenathera pavonina, Alstonia scholaris, Bombax ceiba, Delonix regia, Lagerstroemia speciose, Simarouba glauca* and *Sterculia foetida*. The data on diameter at breast height (DBH), total height, crown spread, and health indicators were processed using the i-Tree Eco model. Study revealed that *Anandabana* stored approximately 44.48 tons of carbon, valued at ₹16.38 lakhs, and sequestered about 8.63 tons of carbon annually, equating to ₹3.18 lakhs per year. Avoided stormwater runoff was also quantified and it was 123.76 l/tree/year with financial gain of Rs. 11,235.81 from the all species. This study highlights both the strengths and limitations of using i-Tree Eco model in urban ecosystems. This offers a rapid and replicable approach for ecosystem service valuation, limitations arise owing to its default parameters, necessitating local calibration for greater accuracy. Despite challenges, this tool could be used to provide baseline data for urban forest management, climate resilience planning, and policy advocacy.

Keywords: Ecosystem services, i-Tree Eco Model, Urban green spaces, Carbon sequestration

Quantifying the value of ecosystem services is vital for highlighting the concrete benefits derived from natural ecosystems and providing justification for financial investments in their establishment and management. This approach is widely acknowledged as critical in environmental economics and policy development, especially when ecosystem services such as carbon storage, air and water filtration, climate regulation, and recreational opportunities lack direct market pricing (Thakur et al., 2011, Attar et al., 2016, Panwar et al., 2022). By assigning monetary value to these services, decision-makers and stakeholders can more effectively evaluate the returns on investments in conserving natural ecosystems and creating protected areas (TEEB 2010). This rationale extends equally to semi –natural ecosystems and curated green spaces in urban settings, such as parks, botanical gardens, green roofs, and landscaped avenues, where significant public and private resources are invested. Although these spaces are not strictly natural, they provide substantial ecosystem services that contribute to human well-being, urban climate resilience, and biodiversity enhancement (Gomez-Baggethun and Barton 2013, Bhusara et al., 2016, Panchal et al., 2017).

According to Millennium Ecosystem Assessment (2005) Ecosystem services are classified into four categories of provisioning, regulating, cultural and supporting services. Though some researchers opine that this classification denotes ecosystem processes for achieving services and the services themselves (Wallace 2007), this is most popularly used classification of ecosystem services. Climate regulation is a regulating service which encompasses several ecological processes to atmospheric composition, the greenhouse effect, the ozone layer, precipitation, air quality, moderation of temperature and weather patterns both at both global and local scales (Costanza et al., 1997). Air pollution mitigation, carbonation, storm water management, urban cooling and water retention remains the most discussed topic among the regulating services of urban ecosystems. There has been a surge in literature on service of the habitat in providing shelter, protection, and nutritional needs of organisms, cultural services and health benefits resulting in overall improvement in the quality of life of citizens in the recent past (Luo and Patuano 2023)

Urban green spaces play a pivotal role in enhancing climate resilience by mitigating the impacts of climate change such as heatwaves and flooding (Kabisch et al., 2016, Hanna et al., 2023). They mitigate the urban heat island effect, reduce local temperatures, and lower the energy costs for cooling (Oberndorfer et al., 2007). They also improve air quality by filtering pollutants and sequestering carbon dioxide (Bolund and Hunhammar 1999, Singkran 2022). They often act as lungs of urban areas and mitigates air pollution (Agbelade and Onyekwelu 2020, Song et al., 2020a,b, Lopez-Lopez et al., 2018). Green roofs and permeable surfaces enhance stormwater management by reducing runoff and improving water quality (Mentens et al., 2006). They contribute to climate resilience by mitigating urban heat islands, with cooling effects up to 7.7°C on surfaces with reductions in energy consumption through insulation and evapotranspiration along with other benefits such as improved air quality (Veerkamp et al., 2021).

Parks and botanical gardens provide recreational opportunities, improve mental health, and foster social cohesion (Chiesura 2004). Access to green spaces has been linked to reduced stress and improved quality of life (Tzoulas et al., 2007). They also support biodiversity by providing habitats for birds, insects, and other species, thereby contributing to ecological connectivity in fragmented urban landscapes (Kong et al., 2010). Enhancing understorey vegetation cover and incorporating native plants increased the species occupancy of birds, bats, and insects in urban green spaces (Threlfall et al., 2017). Carbon sequestration by trees depends on their type, size, health, where they grow, and the biomass generated through physiological transformation. Unlike its natural habitats, carbon sequestration may not be as predictable in cities where site factors vary greatly because of space constraints, poor soil conditions mainly due to compaction with hard pavements, air pollution, and anthropogenic interferences (Nowak et al., 2008). However, there is lack of standardised simple methods to quantify these services and deficiency of data that could be effectively put to use by policy makers and urban ecosystem managers.

There are direct and indirect methods to quantify these valuable services. The i-Tree Eco model, is a scientifically validated and widely used tool for quantifying the structure of urban forests and ecosystem services, such as carbon storage and sequestration (Nowak and Crane 2000, Nowak et al., 2016, Zhou et al., 2021, Davies et al., 2023, Zhang et al., 2024). Systematic evaluations of curated green spaces through methods such as modelling tools (e.g., i-Tree Eco) can substantiate their value and promote their strategic integration into urban planning frameworks. The present study focused on evaluating the ecosystem services, particularly carbon storage and sequestration, provided by trees in a green space within the urban area of Bhubaneswar, using the i-Tree tool application.

MATERIAL AND METHODS

Study area: *Anandabana*, is a planned semi-natural green area created in 2020 as part of the "Nagar Van Yojana" initiative of Ministry of Environment, Forest and Climate Change, Government of India, to promote a healthy and wholesome living environment and to help the nation's cities become cleaner, greener, healthier, and more sustainable. It is located in the western part of the Bhubaneswar city, in the east coastal plain of Odisha, India. It has tropical monsoon type of climate with average annual temperature of 27 °C and annual rainfall of 1450 mm. *Anandabana* is a lush green space spanning over an area of 89.50 acres, located to the North-west of the city (Fig. 1).

Species selection and data collection: The area under study has several species of various ages, planted while curating the space and several others that were already present as the area was earlier a part of an arboraceous

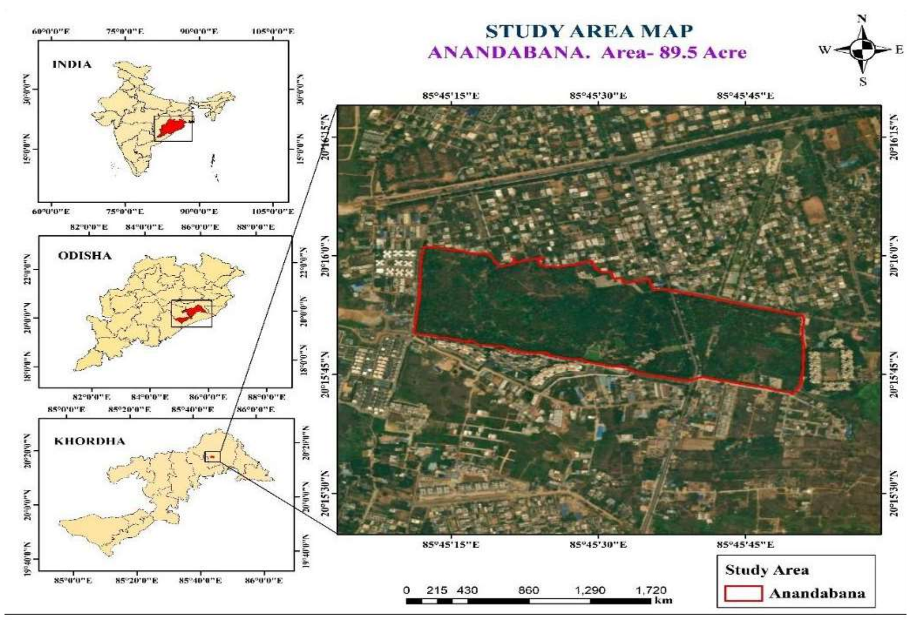

Fig. 1. Study site *Ananadabana*

vegetation. A transect survey was undertaken to document all the tree species. Eight tree species whose scientific names could be validated against the tree data set in the i-tree database were selected for the study. These species were among the ten most prominent tree species in the study area and were available in the presets of the i-Tree Eco software. The species selected and the number of trees considered for assessment are shown in Figure 2.

A total of 484 trees of the eight species were present in the area under study. The parameters (default for the software) that were required for the assessment of carbon and avoided runoff *viz*., Girth at Breast Height (GBH)/Diameter at Breast Height (DBH), height, crown width, crown length, crown light exposure, health of the trees of the eight species tallied were measured using standard methods and recorded.

Software model used for assessment: The software used was i-Tree eco v6.0.38, a peer-reviewed software suite of USDA Forest Service that provides urban and community forestry analysis and assessments (*itreetools.org*).

RESULTS AND DISCUSSION

The studied species showed considerable variation in their C storage and C sequestration potential, indicating that the tool could not only be employed for a quick understanding of the value of ecosystem services, but also for a deeper understanding of the C sequestration and storage potential of the species. A total of 44.48 tons of carbon**,** generating over ₹16.37 lakhs was assessed to have been sequestered from the data provided (Table 1). S*imarouba glauca* contributed roughly 40% of the total carbon and approximately 40% of the total revenue**,** despite being less than 20% of the trees in number. S. *glauca* trees of diameter 10–20 cm reportedly produced ~ 57.80 kg of biomass per tree, more than five-year-old tree plantation which stored 2.73 t of C/ha (Mohamed et al., 2016, Anil 2009). Although per-ton profitability seems uniform (₹/ton is constant), species with higher total carbon yielded more revenue (Table 1). *B. ceiba***,** stored only 1.06 t, bringing in proportionally less financial gain (₹39,195). *A. auriculiformis* also showed low carbon performance (~0.02 t/tree) in this study. The annual financial gain amounted to ₹3,17,904, and the total C sequestered by 484 trees was 8.63 tonnes /year (Table 2). *S. glauca,* despite being just 20% of the total trees, contributed to approximately 32% of the total carbon sequestered and 32% of the total estimated revenue.

The collected data also provided estimates of the avoided runoff in litres and the resultant financial gains from the avoided runoff (Table 3). The economic evaluation of storm water runoff avoidance provided by various tree species in an urban green space summed up to ₹11,235 per year. The trees in all avoided runoff of 59897.97 litres per year, equivalent to approximately 60 cubic meters of water saved annually (Table 3). *A. pavonina* contributed the most (15,297.57 l/yr), despite having only 57 trees, owing to its high per-tree efficiency. *D. regia* had the highest per-tree value (284.99 l/tree/year), indicating that it is highly effective for in front of runoff prevention on a per-tree basis. *A. auriculiformis* had a lower per-tree rate (31.03 l/tree/year), but its large numbers made it a significant contributor overall. The total average across all trees was 123.76 l/tree/year as indicated by the results of this study.

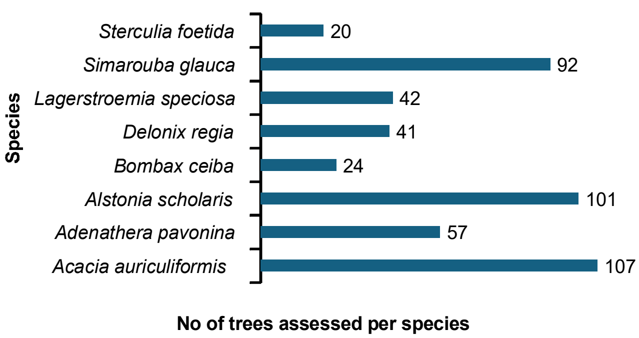

Fig. 2. Species and number of trees assessed

Table 1. Total carbon stored and estimated financial gain

Species	No of trees	Total C stored (tons)	Stored C/tree (Kg)	Estimated financial gain (₹)*
Acacia auriculiformis	107	2.03	18.97	74,784
Adenathera pavonina	57	6.75	118.42	2,48,532
Alstonia scholaris	101	5.35	52.97	1,96,837
Bombax ceiba	24	1.06	44.17	39,195
Delonix regia	41	4.82	117.56	1,77,384
Lagerstroemia speciosa	42	5.32	126.67	1,95,843
Simarouba glauca	92	17.64	191.74	6,49,707
Sterculia foetida	20	1.51	75.50	55,522
Total	484	44.48		16,37,808

*The values have been provided by the i-Tree tool, the exchange value for C is estimated at ₹200/ton, which is the international standard as taken for assessment by the i -Tree model

Several studies have indicated the use of i-tree tools coupled with other remote sensing methods for holistic and reliable estimation of both natural and curated spaces (Prigioniero et al., 2022, Sharma et al., 2024, Sharma et al., 2025). Analysis of the available data revealed comparable carbon sequestration rates for *A. auriculiformis*, but notable variations were observed for *A. scholaris*, *Bombax ceiba*, and *D. regia* (Table 4). *L. speciosa* demonstrated consistently

Table 2. Total C sequestered and estimated financial gain per year

Species	No. of trees	Total C sequestered (tons/year)	Sequestered C/tree/Year (Kg)	Estimated financial gain (₹/yr)*
Acacia auriculiformis	107	0.59	5.514	21,814
Adenathera pavonina	57	1.66	29.12	61,293
Alstonia scholaris	101	1.12	11.09	41,145
Bombax ceiba	24	0.25	10.42	9,110
Delonix regia	41	0.87	21.22	31,954
Lagerstroemia speciosa	42	1.12	26.67	41,097
Simarouba glauca	92	2.76	30.00	1,01,557
Sterculia foetida	20	0.27	13.50	9,930
Total	484	8.63		3,17,904

*The values have been provided by the i-Tree tool, the exchange value for C is estimated at Rs. 200/ton, which is the international standard as taken for assessment by the i -Tree model

Table 3. Avoided run-off by species under study and the estimated financial gain

Species	No. of trees	Avoided runoff (l/yr)	Avoided runoff (l/tree/year)	Estimated financial gain (Rs/Yr)
Acacia auriculiformis	107	3319.82	31.03	622.74
Adenathera pavonina	57	15297.57	268.38	2869.55
Alstonia scholaris	101	10736.23	106.30	2013.93
Bombax ceiba	24	2107.60	87.82	395.35
Delonix regia	41	11684.41	284.99	2191.79
Lagerstroemia speciosa	42	4088.97	97.36	767.02
Simarouba glauca	92	9705.08	105.49	1820.5
Sterculia foetida	20	2958.32	147.92	554.93
Total	484	59897.97	123.76	11,235.81

Table 4. Comparative review on carbon sequestered reported earlier case studies and present study

Name of the species	DBH (cm)	Height (m)	Carbon stored kg/tree	Carbon Sequestered kg/tree/year	Reference
Acacia auriculiformis	14.83	4.84	18.97	5.51	Current study
Acacia auriculiformis	Not specified	Not specified	18.60	7.77	Sharma et al. (2021)
Alstonia scholaris	17.14	6.36	52.97	11.09	Current study
Alstonia scholaris	Not specified	Not specified	55.36	55.27	Dadhich et al. (2023)
Bombax ceiba	18.11	5.82	44.17	10.42	Current study
Bombax ceiba	241.15	14.26	436.2	1599.00	Korra Simhadri et al. (2016)
Delonix regia	23.31	9.67	117.56	21.22	Current study
Delonix regia	270	16.09	520.41	1908.00	Korra Simhadri et al. (2016)
Lagerstroemia speciosa	19.73	6.25	126.67	26.67	Current study
Lagerstroemia speciosa	Not specified	Not specified	19.10	19.07	Sharma et al. (2021)
Sterculia foetida	19.17	8.32	75.50	13.50	Current study
Sterculia foetida	80.89	Not specified	71.00	5.92	Amir et al. (2024)

high carbon sequestration across different locations in India, with rates of 26.67 kg/tree/year and 19.07 kg/tree/year elsewhere, suggesting its reliability in urban planting initiatives. *S. foetida* exhibited moderate sequestration of 13.5 kg/tree/year in *Anandabana*. Based on the findings of this study, both *L. speciosa* and *A. scholaris* emerged as dependable and effective choices for urban carbon sequestration programs.

The comparisons presented here serve as illustrative examples of carbon sequestration estimates for the studied species and should not be used to evaluate the superiority of any estimation method, as site-specific conditions significantly influence tree growth and sequestration outcomes. Reports of avenue trees storing approximately 1016.15 metric tons of carbon, with an annual carbon sequestration of 25.69 tons using i-tree tools (Watson and Bhai 2025) indicates an acceptance of this tool as a feasible option for qualification of ecosystem services in Indian context and its use in air pollution management strategies in urbanized regions (Vashist et al., 2024).

CONCLUSION

The i-Tree Eco tool offers a rapid and effective approach for assessing carbon sequestration and storage in urban and managed forests, delivering both biophysical estimates and economic value of these services with limited inputs. Study indicated that *Anandabana* stored approximately 44.48 tons of carbon, valued at ₹16.38 lakhs, and sequestered about 8.63 tons of carbon annually, equating to ₹3.18 lakhs per year. Avoided storm water runoff was also quantified and it was 123.76 l/tree/year with financial gain of ₹11,235.81 from the all species. While i-Tree Eco model offers a rapid and replicable approach for ecosystem service valuation, limitations arise owing to its default parameters, necessitating local calibration for greater accuracy. Despite challenges, this tool could be used to provide baseline data for urban forest management, climate resilience planning, and policy advocacy. This study has examined only the explorative aspect where the feasibility of an available information was analysed in a local context and would reiterate the tools wider applicability for several other services.

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AUTHOR'S CONTRIBUTION

Sanchit Mohanty, Keshaba Sahoo, Satyajit Nayak, Krishanlal Paramanik, were involved in the project work. T. L. Mohanty, H. Nayak, M. C. Behera, Smitha G Nair provided research inputs for formulation of the project.

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